

# High Energy Cosmic Particles

## photons, leptons, baryons

Panel Members:

Jim Buckley (Wash. Univ.), Stefan Funk (Stanford/SLAC), Tom Gaisser (Univ. Delaware/Bartol), Julie McEnery (NASA/GSFC), Teresa Montaruli (Univ. Wisc., Madison)

Moderator: Angela Olinto (Univ. of Chicago)

# OFFICE OF HIGH ENERGY PHYSICS



U.S. DEPARTMENT OF  
**ENERGY**

NUMI HORN THAT FOCUSES THE  
PARTICLE BEAM FOR THE MINOS  
NEUTRINO EXPERIMENT AT FERMILAB

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## EXPLORING THE QUANTUM UNIVERSE

### HIGH ENERGY PHYSICS ADVISORY PANEL (HEPAP)

[About HEPAP Federal Advisory \(FACA\)](#) and [Current HEPAP Charter](#)

[Meeting Schedule](#)

(Updated March 18, 2011)

[HEPAP Reports](#)

(Updated March 3, 2011)

[Agendas, Talks, Minutes & Summary Letters](#)

(Updated March 18, 2011)

[Current Membership](#)

(Posted March 8, 2011)

[Current HEPAP Subpanels](#)

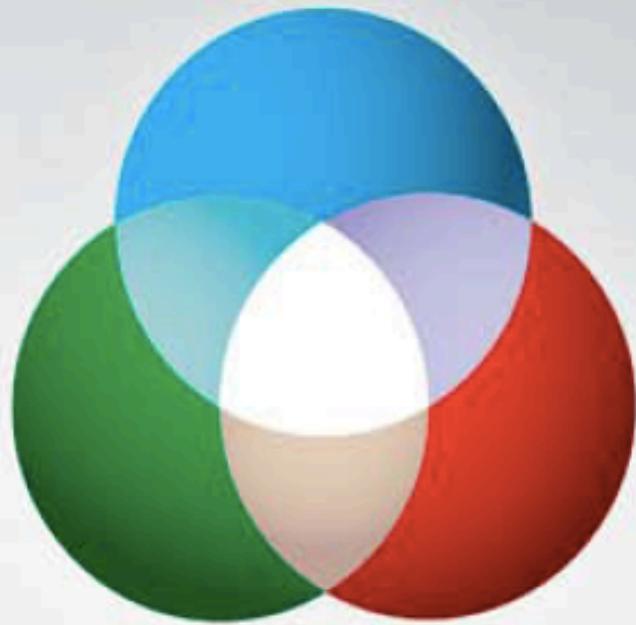
(Updated March 3, 2011)

Last Updated: March 18, 2011

*For Comments or Questions in regards to the High Energy Physics Advisory Panel's section of this website, please contact [Kathy Yarmas](#), at U.S. DOE-HEP*

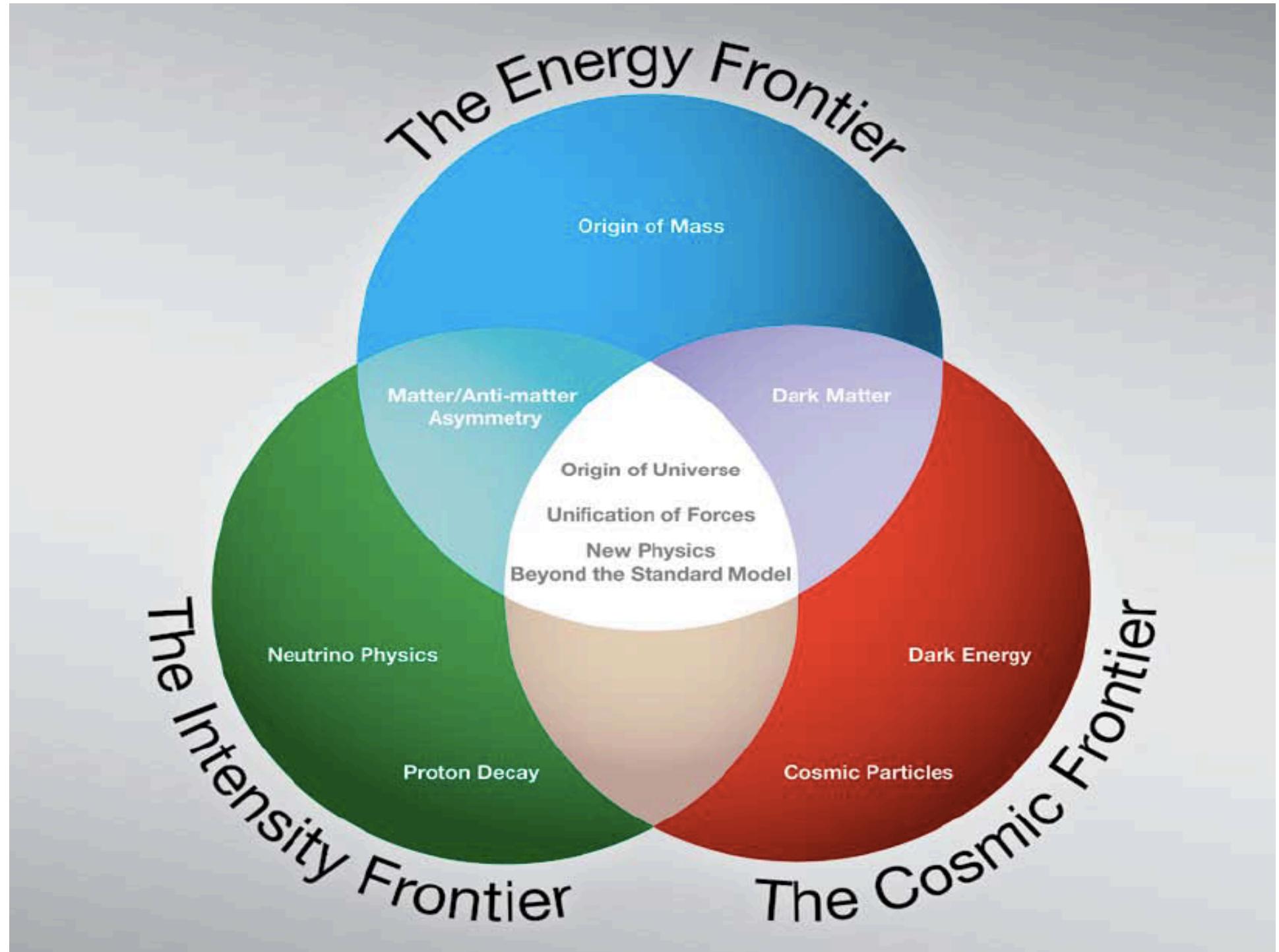
#### In This Section:

- [DOE High Energy Physics Reports](#)
- [HEPAP – High Energy Physics Advisory Panel](#)
- [HEPAP Reports](#)



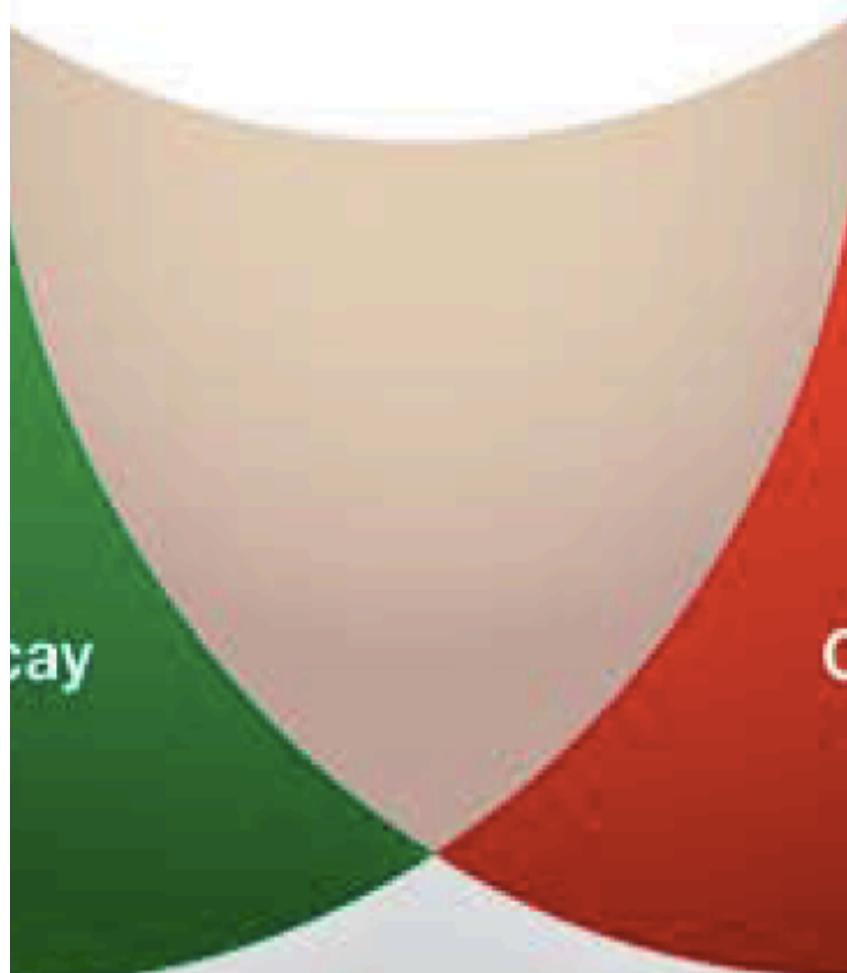
# US Particle Physics: Scientific Opportunities A Strategic Plan for the Next Ten Years

Report of the Particle  
Physics Project  
Prioritization Panel



New Physics

Beyond the Standard Model



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Dark Energy

Cosmic Particles

The Cosmic Frontier

# Cosmic Particles

# High Energy Cosmic Particles

## photons, leptons, baryons

Panel Members:

Tom Gaisser

Teresa Montaruli

Jim Buckley, Stefan Funk, Julie McEnery

Moderator: Angela Olinto

# High Energy Cosmic Particles

photons, leptons, baryons

Panel Members:

Tom Gaisser - baryons

Teresa Montaruli - leptons = neutrinos

Jim Buckley, Stefan Funk, Julie McEnery - photons

Moderator: Angela Olinto

# Overview

## Science:

### Non Thermal Universe: Astro Accelerators

Astro Accelerators reach Extremely High Energies:  $10^{20}$  eV

Astro Accelerators produce baryons, leptons, and photons:  
power laws; over 20 orders of magnitude in energy.

Astro Accelerators are ill understood (origin of Cosmic Rays? Galactic?  
Extragalactic?)

### Dark Matter:

Indirect detection: anti-baryons, photons, positrons, neutrinos

### New Physics - Serendipity

solar, atmospheric, SN neutrinos => neutrino oscillations & masses

Lorentz Invariance tests

Early Universe relics (in addition to Dark Matter)

## Tools:

Present: **Auger, TA, IceCube, VERITAS, HESS, Magic, Fermi**

Future: JEM-EUSO?, **ARA**, CTA?, **HAWC**

R&D: Radio & Microwave (**CR & v**), SC telescope for CTA

# Science Questions

High Energy Cosmic Particles probe interactions past the TeV scale:

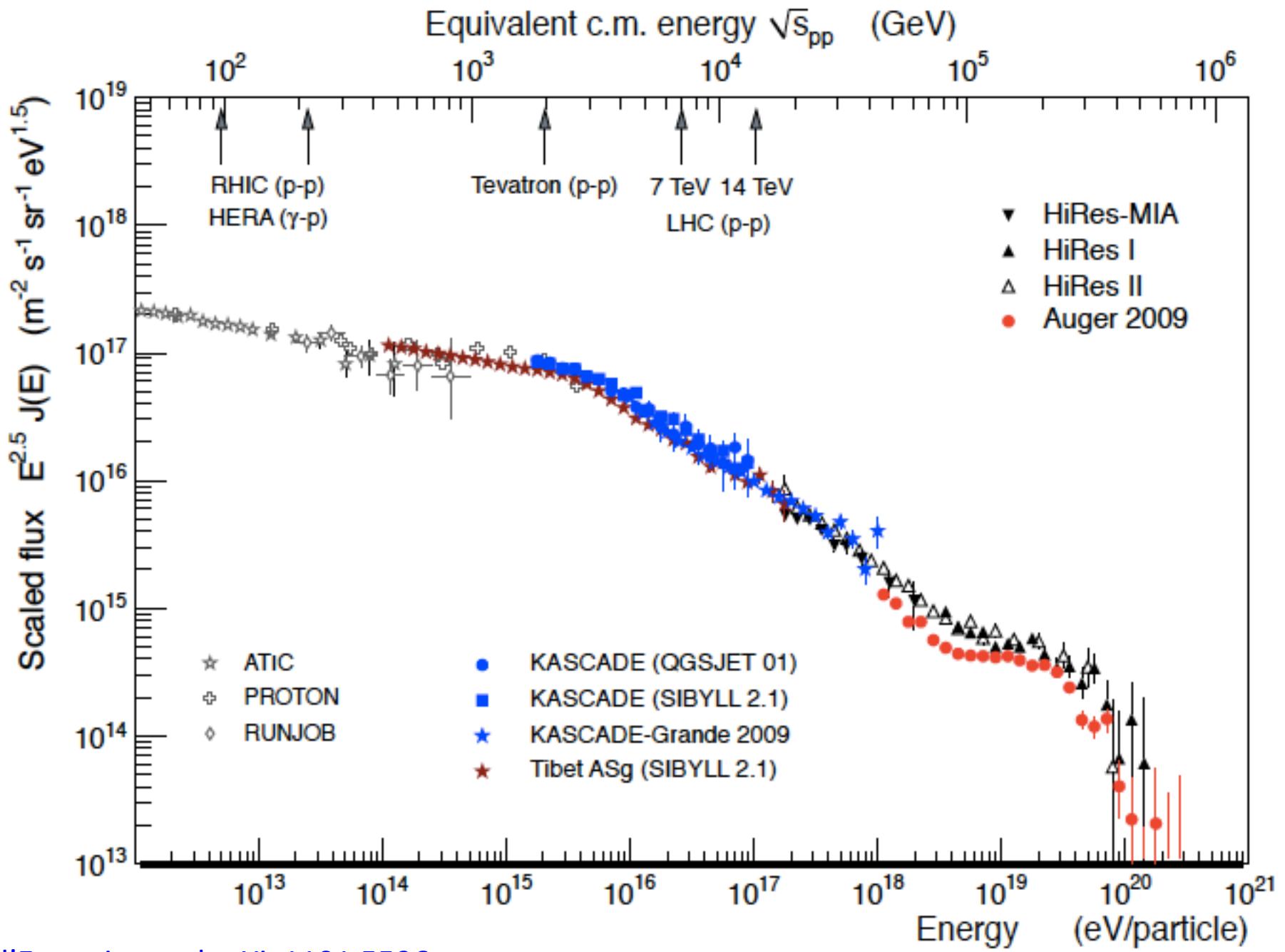
**Cosmic Rays** reach above  $10^{20}$  eV: CM  $> 100$  TeV

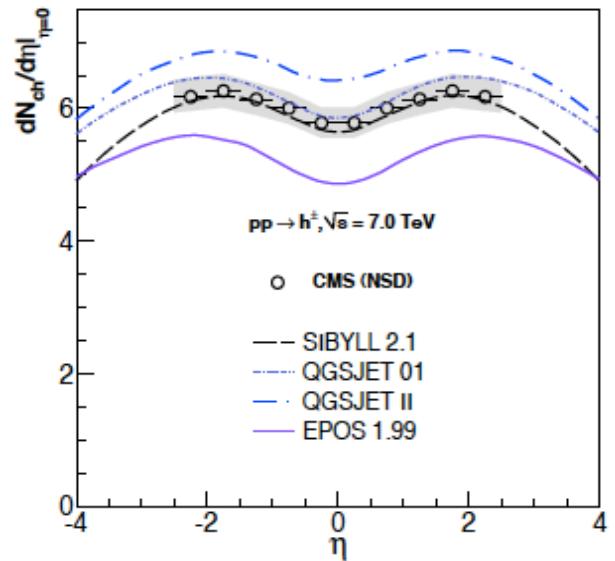
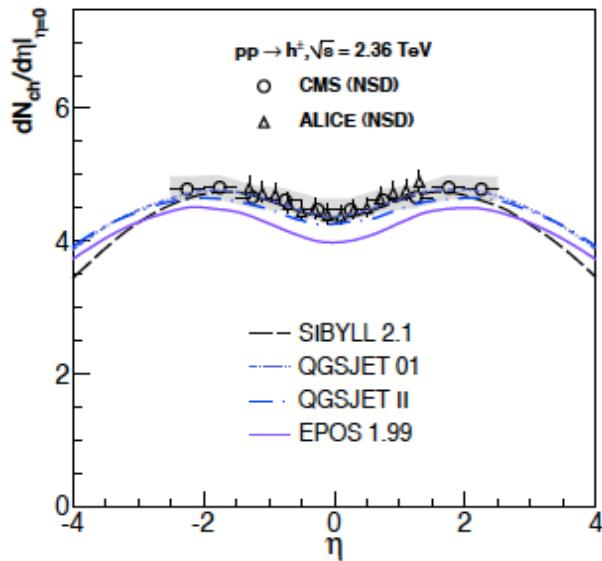
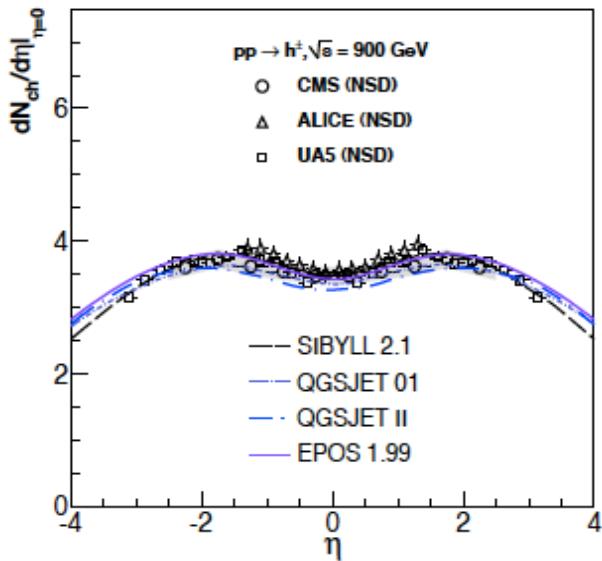
Ultrahigh energies **Neutrinos** and **Gamma-rays**

produced by UHE CRs should be detectable

**Dark Matter** may be a particle with mass  $>$  TeV

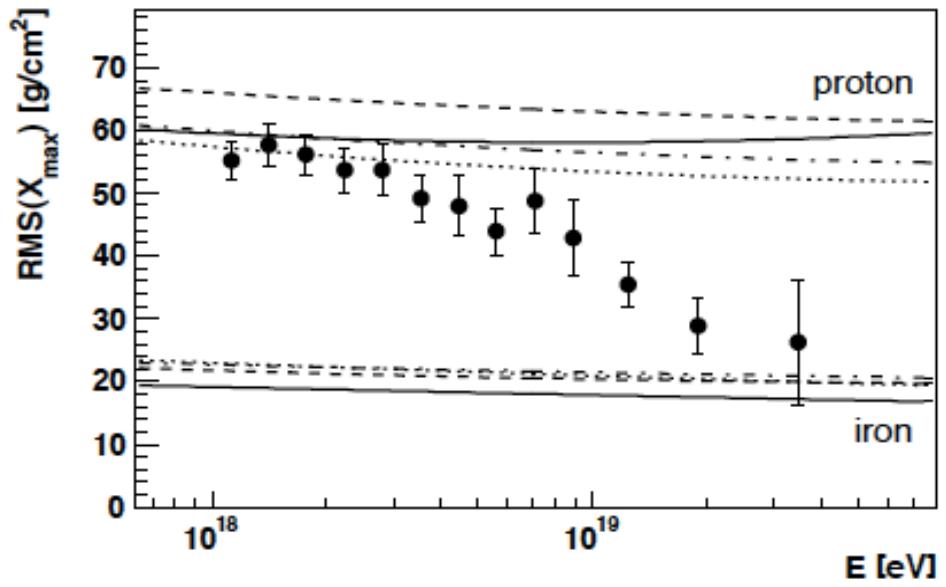
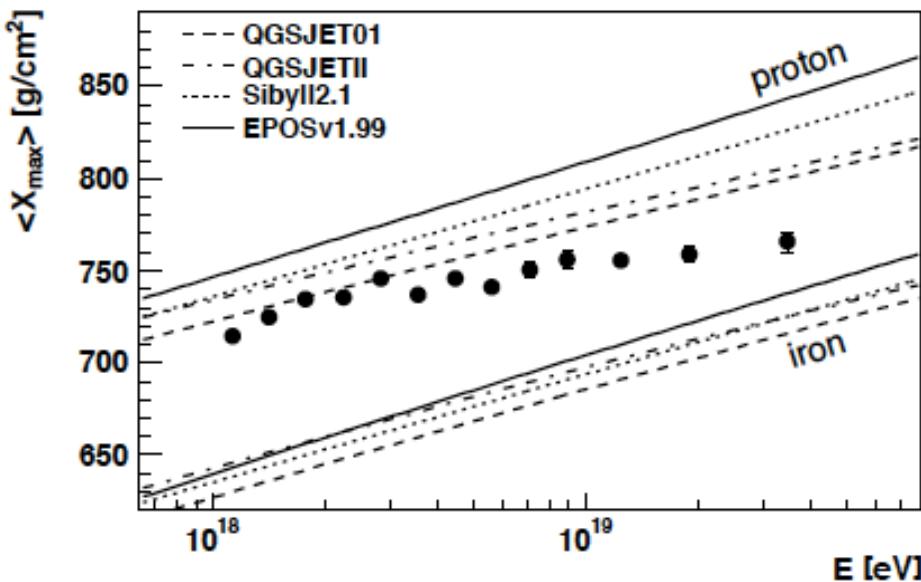
decay products detectable with **Gamma-rays,**  
**Neutrinos, positrons, anti-baryons**





d'Enterria, et al arXiv1101.5596

## LHC & UHECRs



PRL 104 (2010) 091101

# Warning!!!

Need to understand **some** of the **Astrophysics** to be able to use High Energy Cosmic Particles to probe fundamental Physics.

# Science Questions

## The Non-thermal Universe

how high an energy do cosmic accelerators reach?

what are the acceleration mechanisms

sources in the Galaxy? Extragalactic sources?

where is the transition?

what is the composition of Cosmic Rays?

how do Cosmic Rays affect galaxy dynamics?

magnetic fields in galaxies and between them?

what are their magnitude and structure?

how were they generated?

accelerators in the Solar Neighborhood?

What is the High Energy Neutrino Flux on Earth?

# Science Questions

What is the High Energy Neutrino Flux on Earth?

Tests of neutrino cross sections  $E \gg \text{TeV}$

through down vs. up fluxes or horizontal vs upward tau showers

Neutrino masses & mixing angles from CRs & SN

Searches for Dark Matter

If dark matter = particle relics; does it decay or annihilate?

can we detect the products?

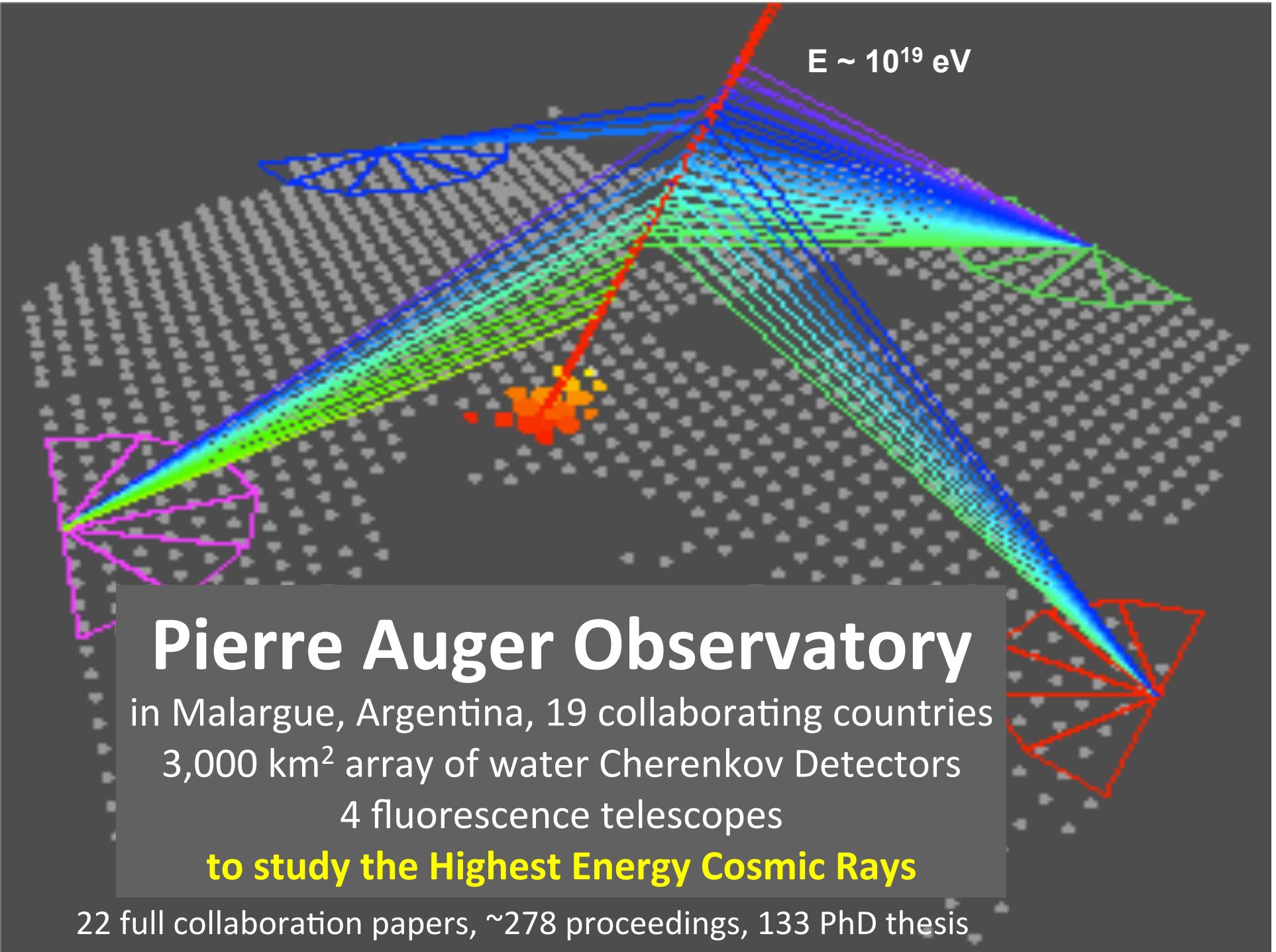
photons, leptons, baryons

can we separate the products from astrophysical non-thermal sources?

Serendipity

Other relics from early universe: topological defects, primordial black holes

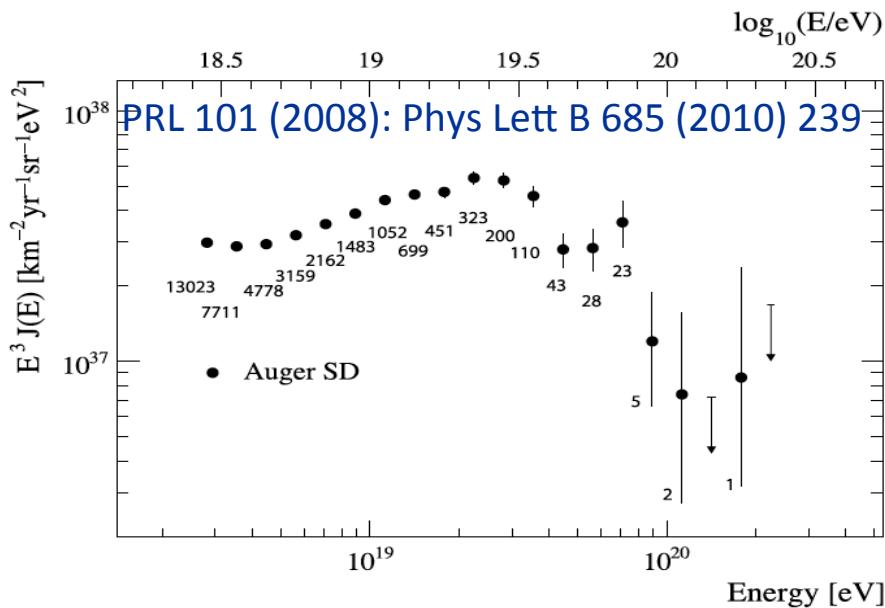
Lorentz Invariance tests



# Some Auger Results

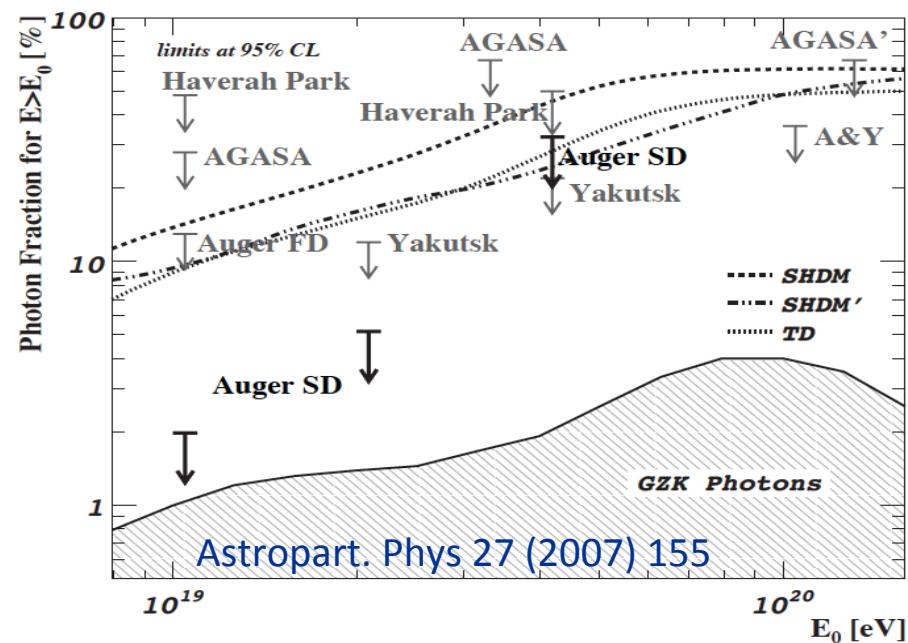
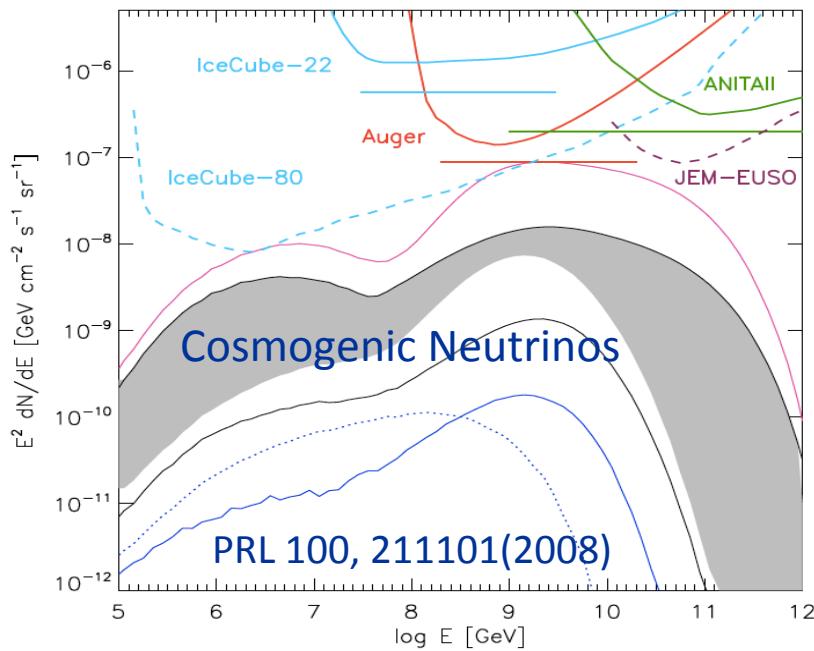
**Spectrum of UHECRs:** significant changes from  $10^{18}$  eV to  $10^{20}$  eV

**Maximum Accelerator Energy? OR  
Greisen-Zatsepin-Kuzmin feature?**



**limit neutrinos from  $10^{17}$  to  $10^{19}$  eV:** Cosmogenic neutrinos?

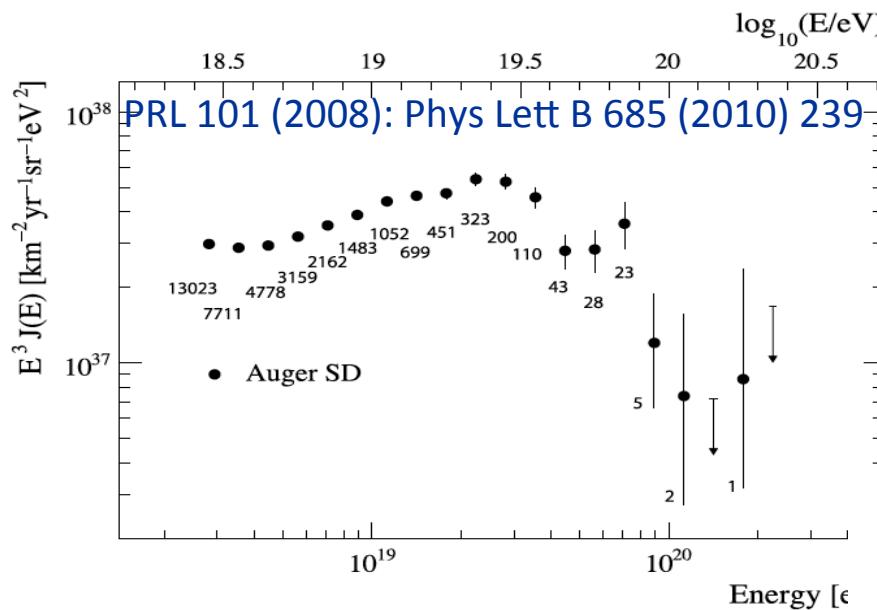
**-limit photons  $10^{19}$  to  $10^{20}$  eV:** Constrained Top-Down Models: SuperHeavy DM, Topol. Defects



# Some Auger Results

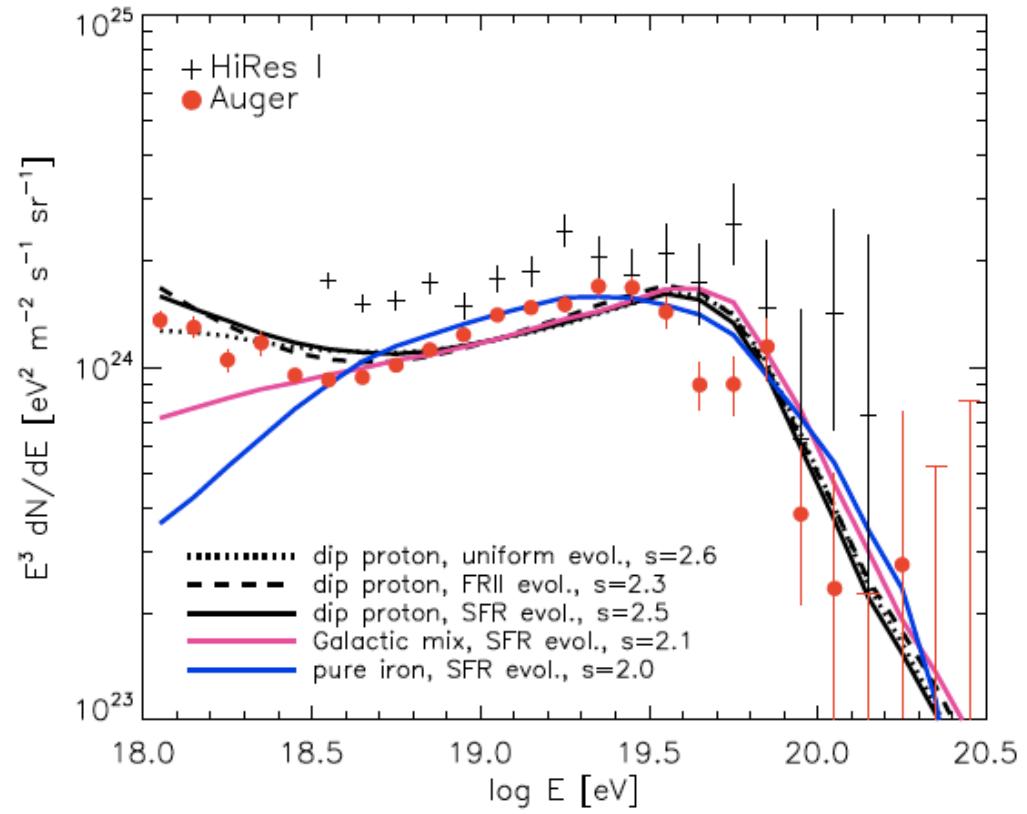
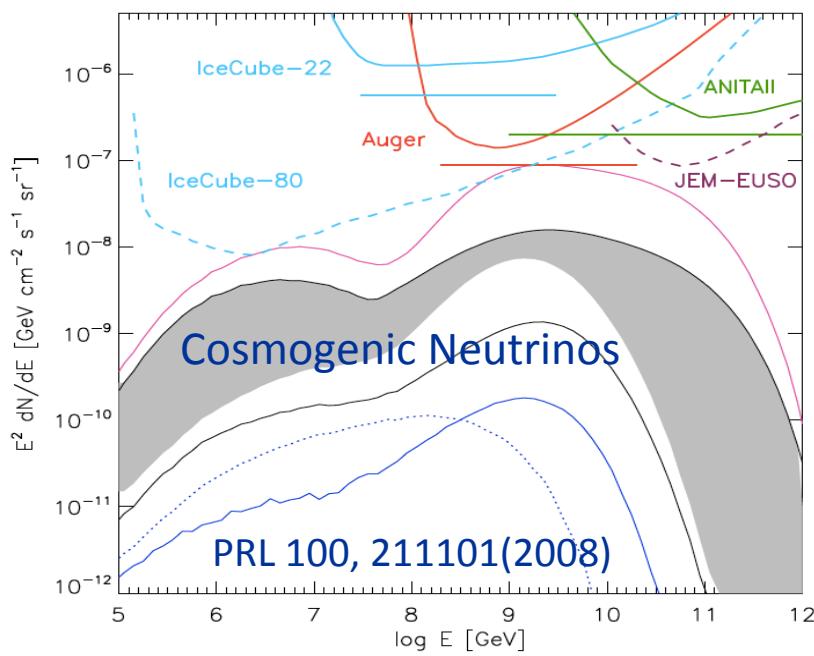
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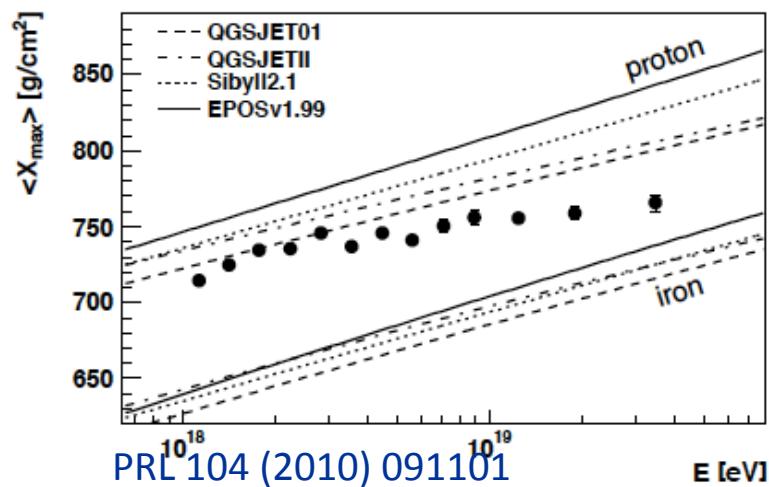
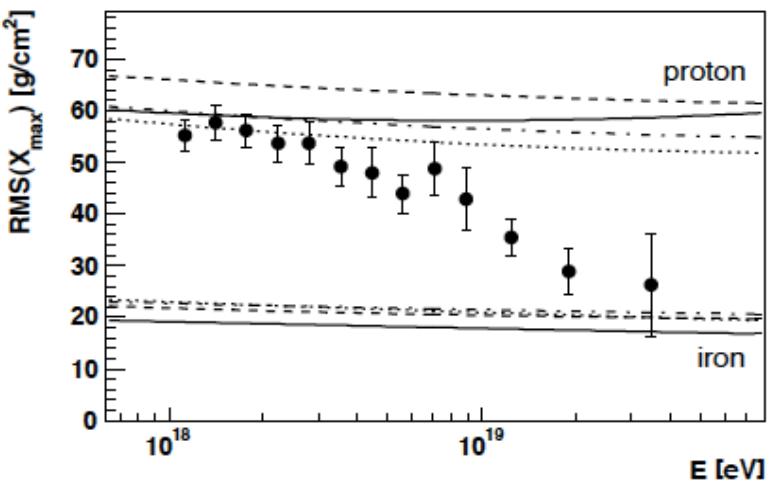
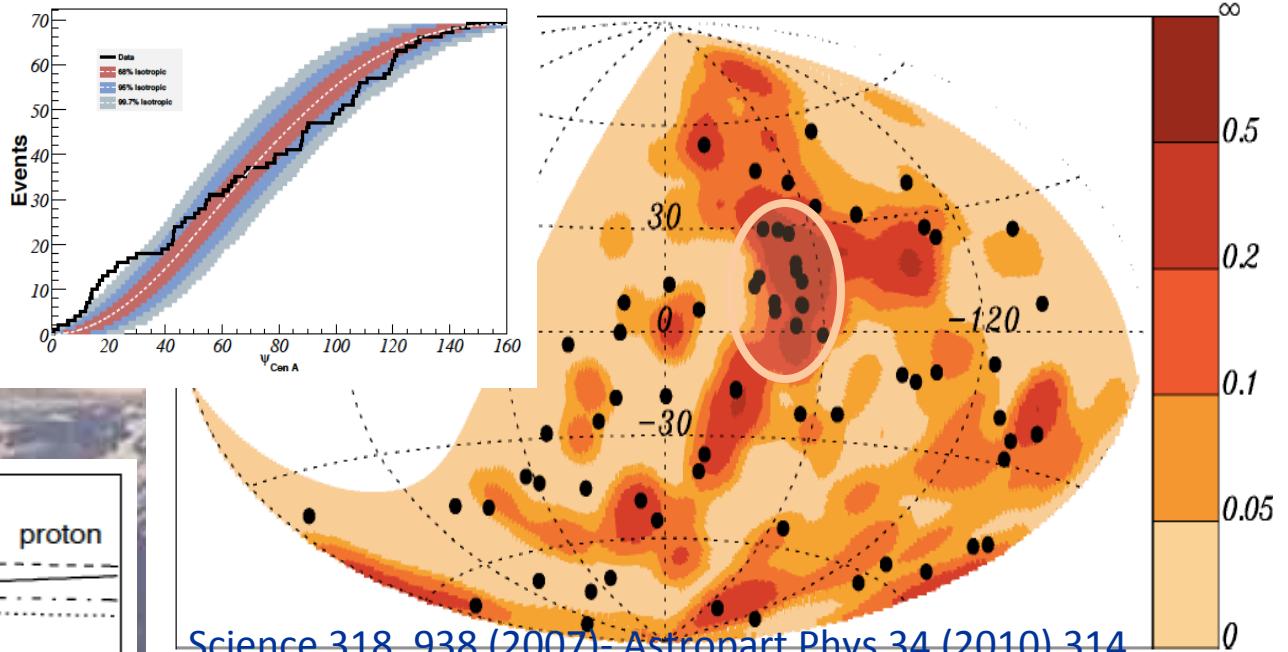


limit neutrinos from  $10^{17}$  to  $10^{19}$  eV:

Cosmogenic neutrinos?



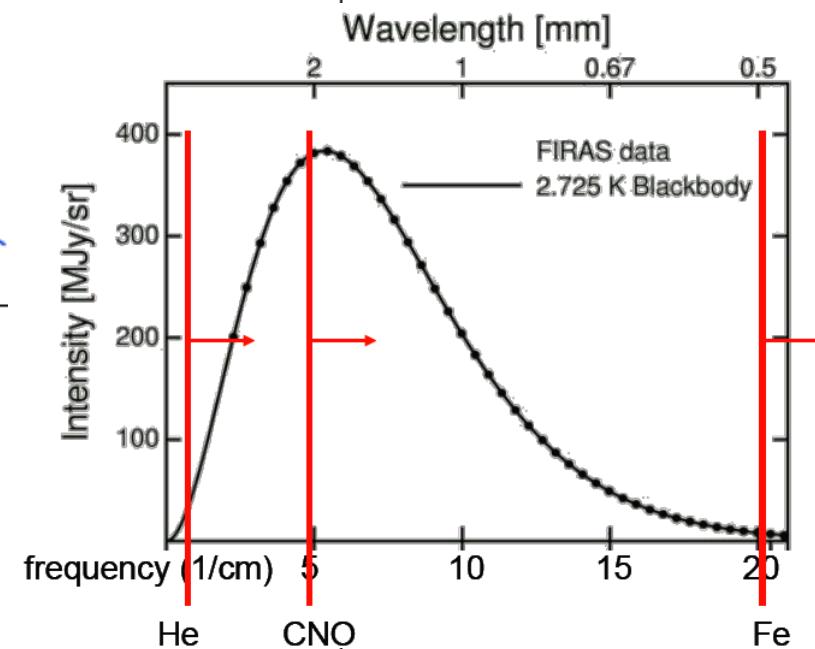
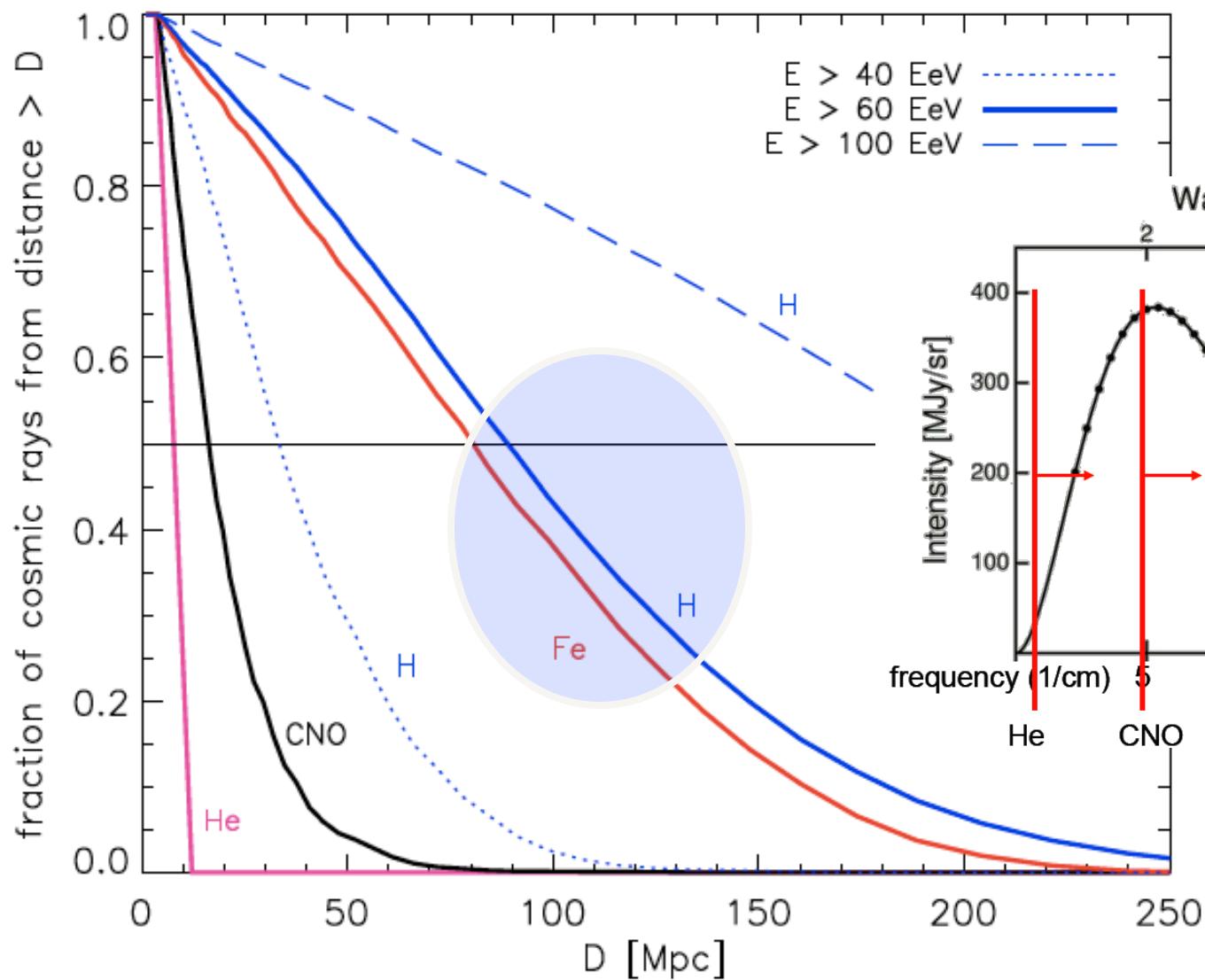
Sky distribution of events  
 $E > 5.5 \cdot 10^{19}$  eV: Anisotropic!  
 Large Scale Structure?  
 Protons?  
 OR Cen A is 1<sup>st</sup> source?



Tension between  
 these two results

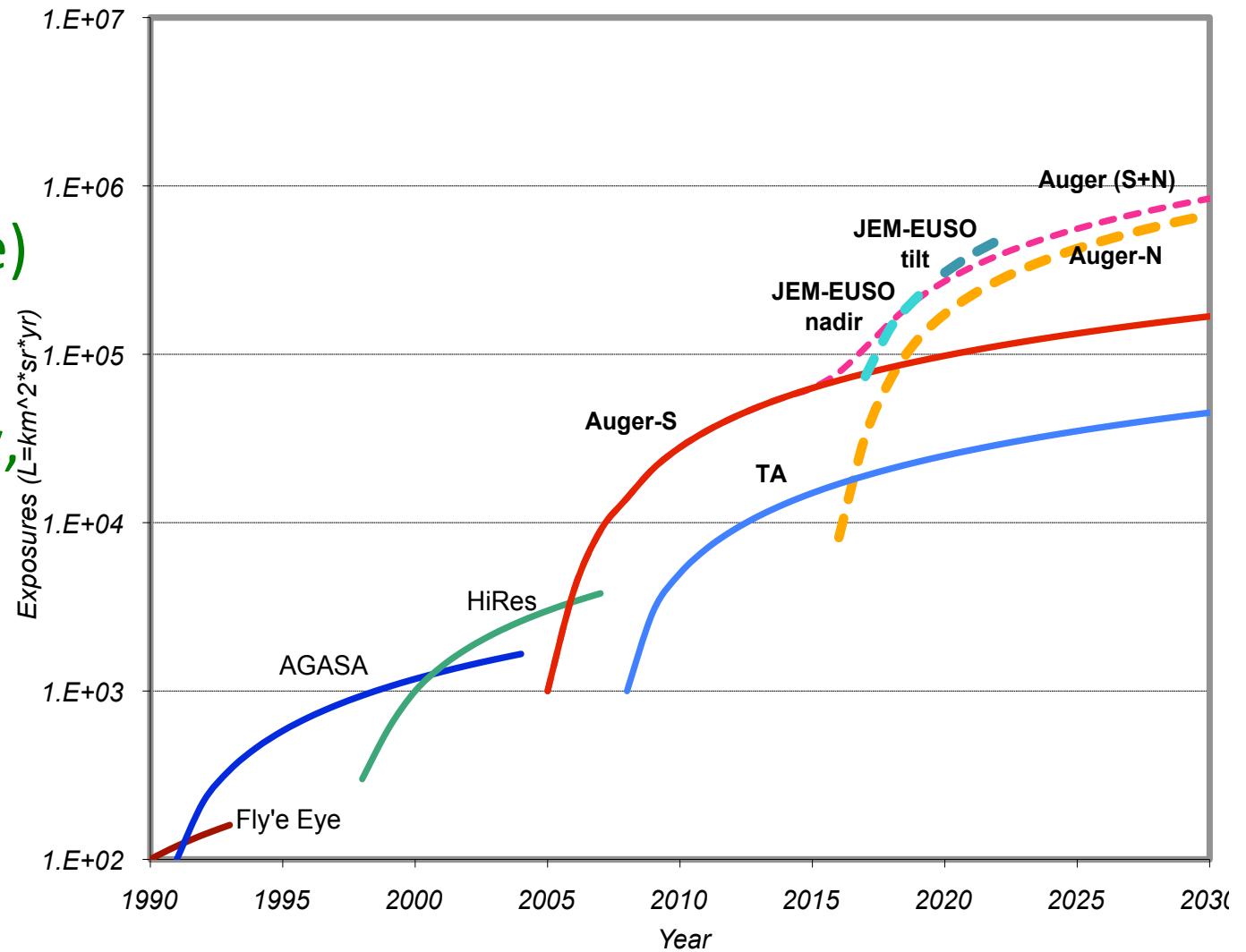
Shower properties: up to  $4 \cdot 10^{19}$  eV  
 from Protons to Iron? OR  
 Change Interactions  $\sim 100$  TeV CM

# GZK Horizon



# Tools for HE Cosmic Rays: Present/Future

Ground arrays  
(IceTop, Kascade)  
Auger South,  
Telescope Array,  
Auger North?  
Space  
balloons,  
JEM-EUSO?



# Tools for HE Cosmic Rays: Present/Future

Ground arrays

(IceTop,Kascade)

Auger South,

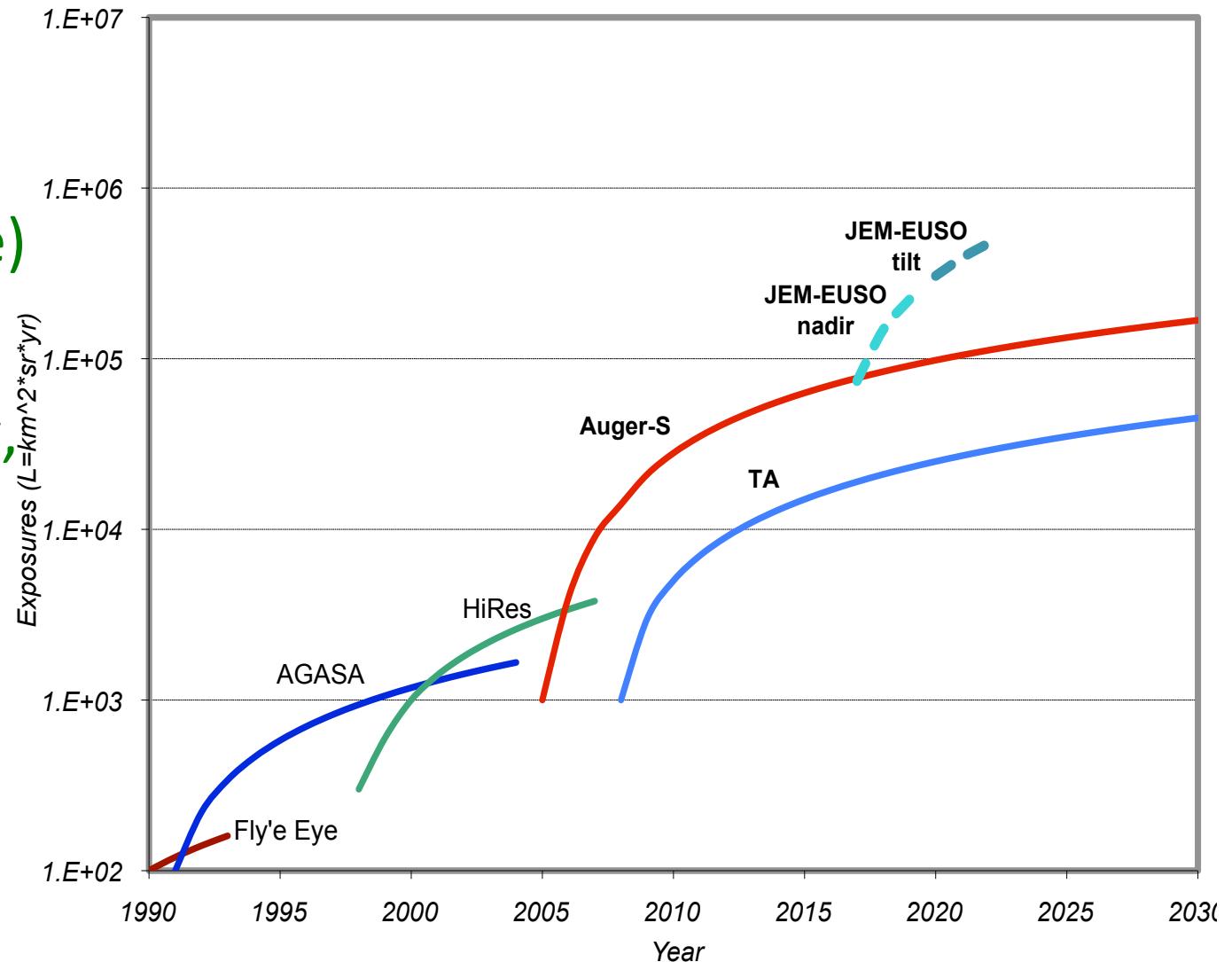
Telescope Array,

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# Tools for HE Cosmic Rays: Present/Future

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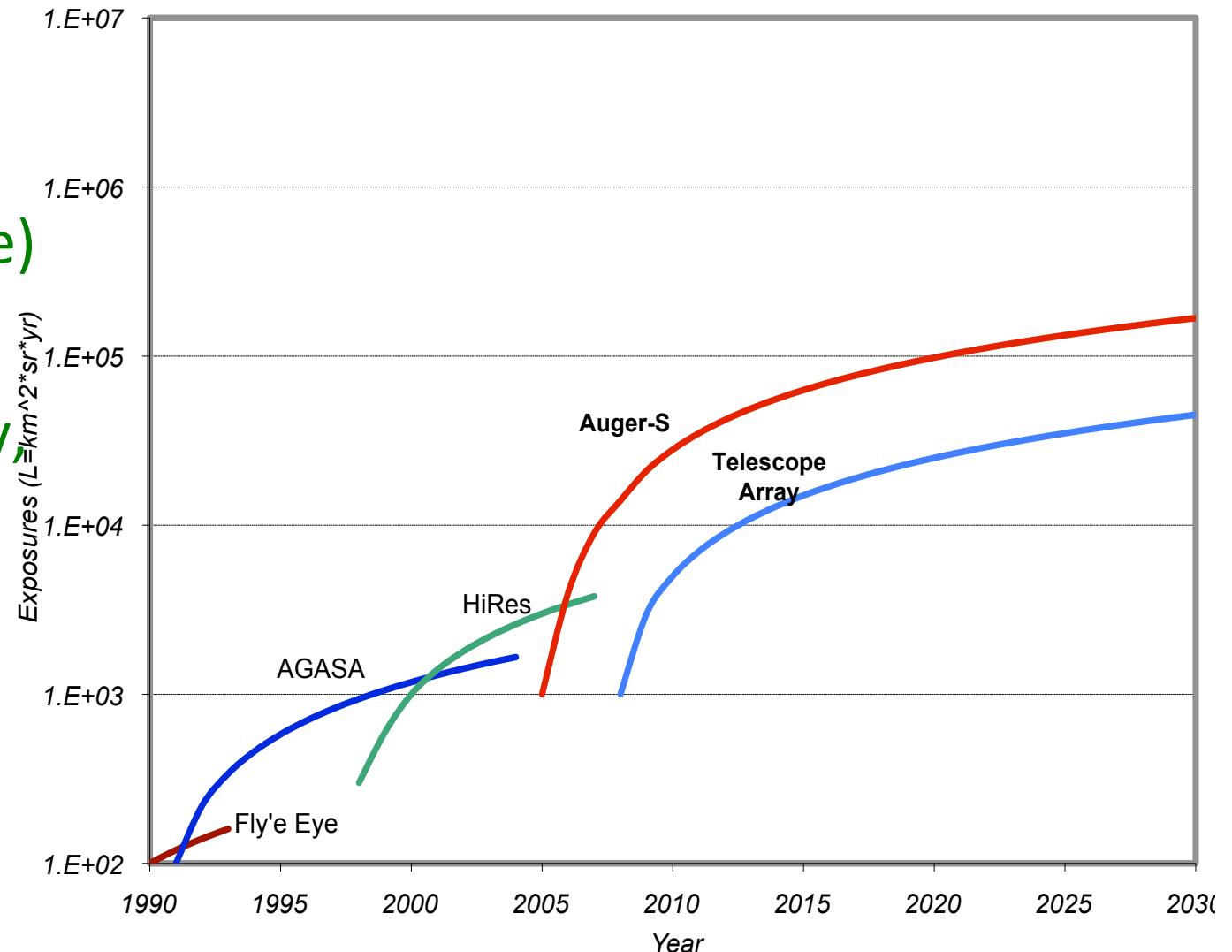
Telescope Array

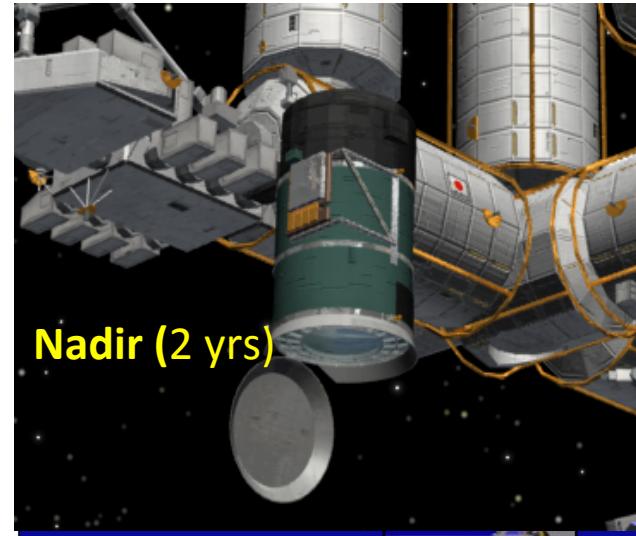
Auger North?

Space

balloons,

JEM-EUSO?

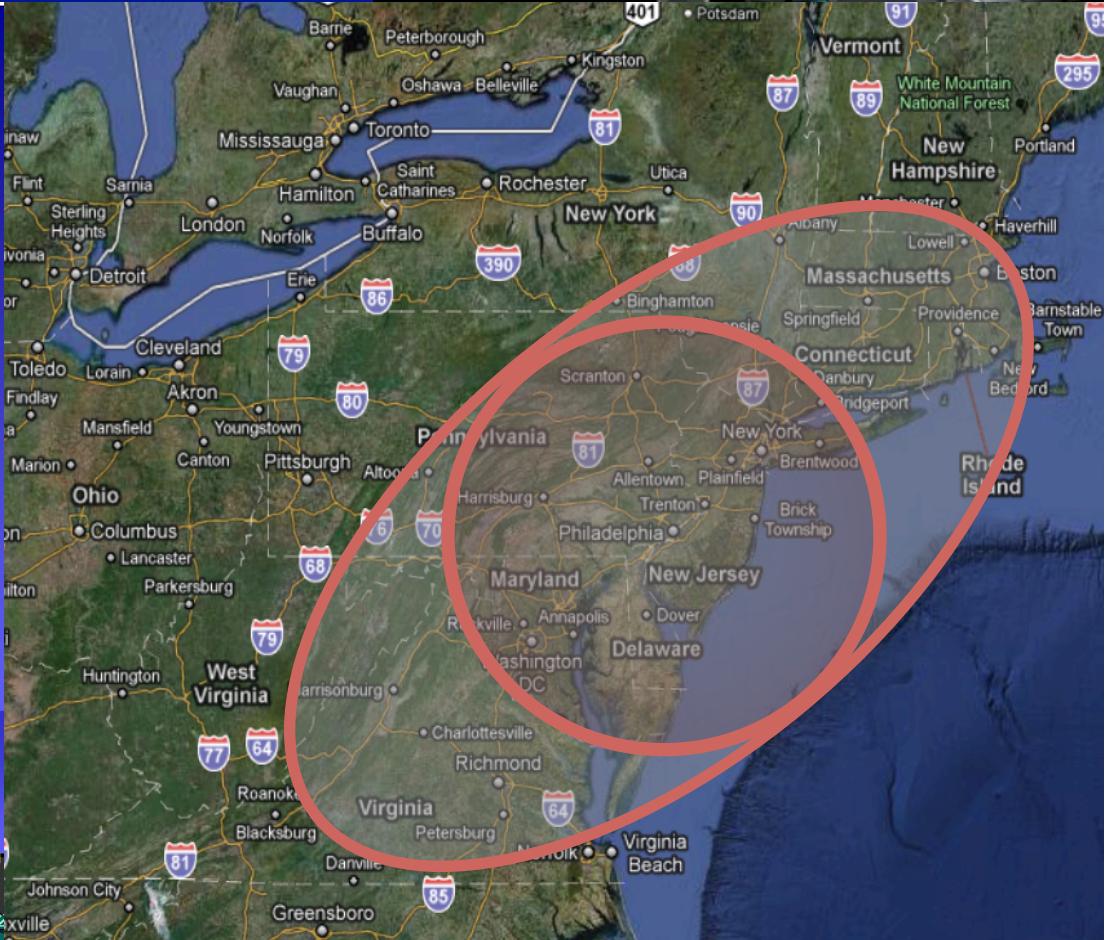
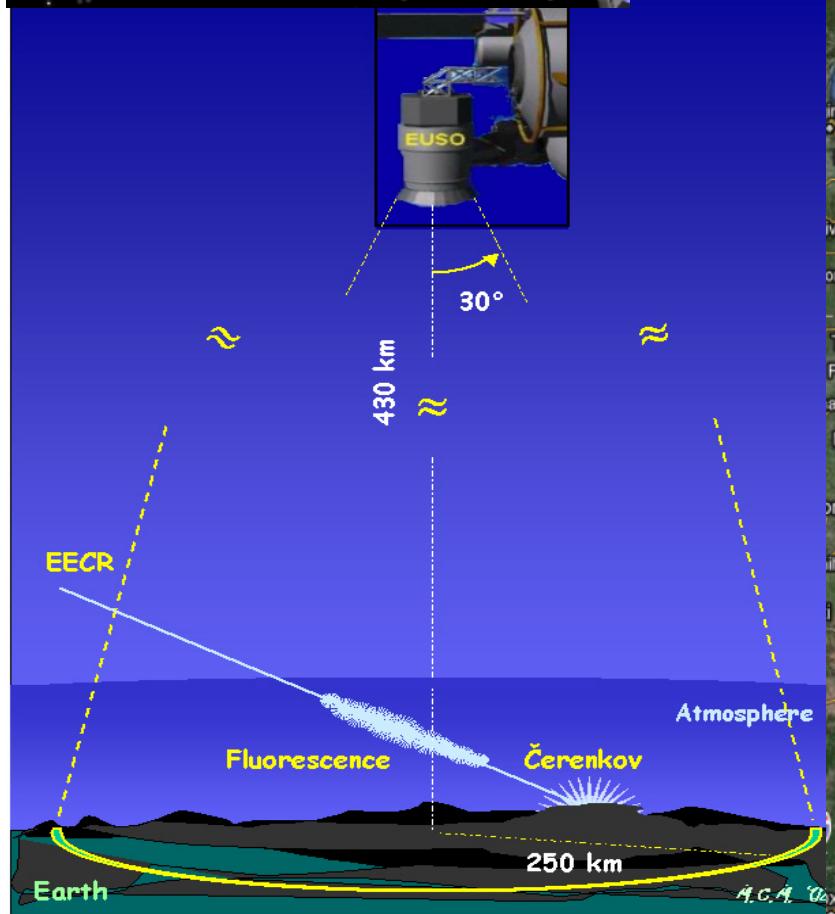
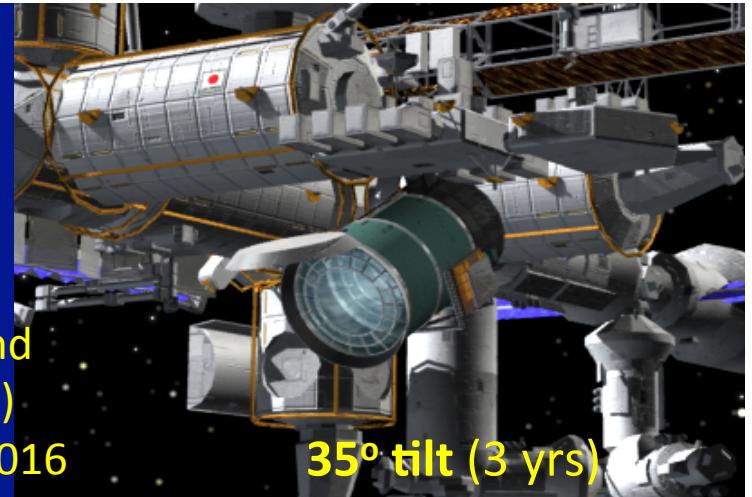




# JEM-EUSO

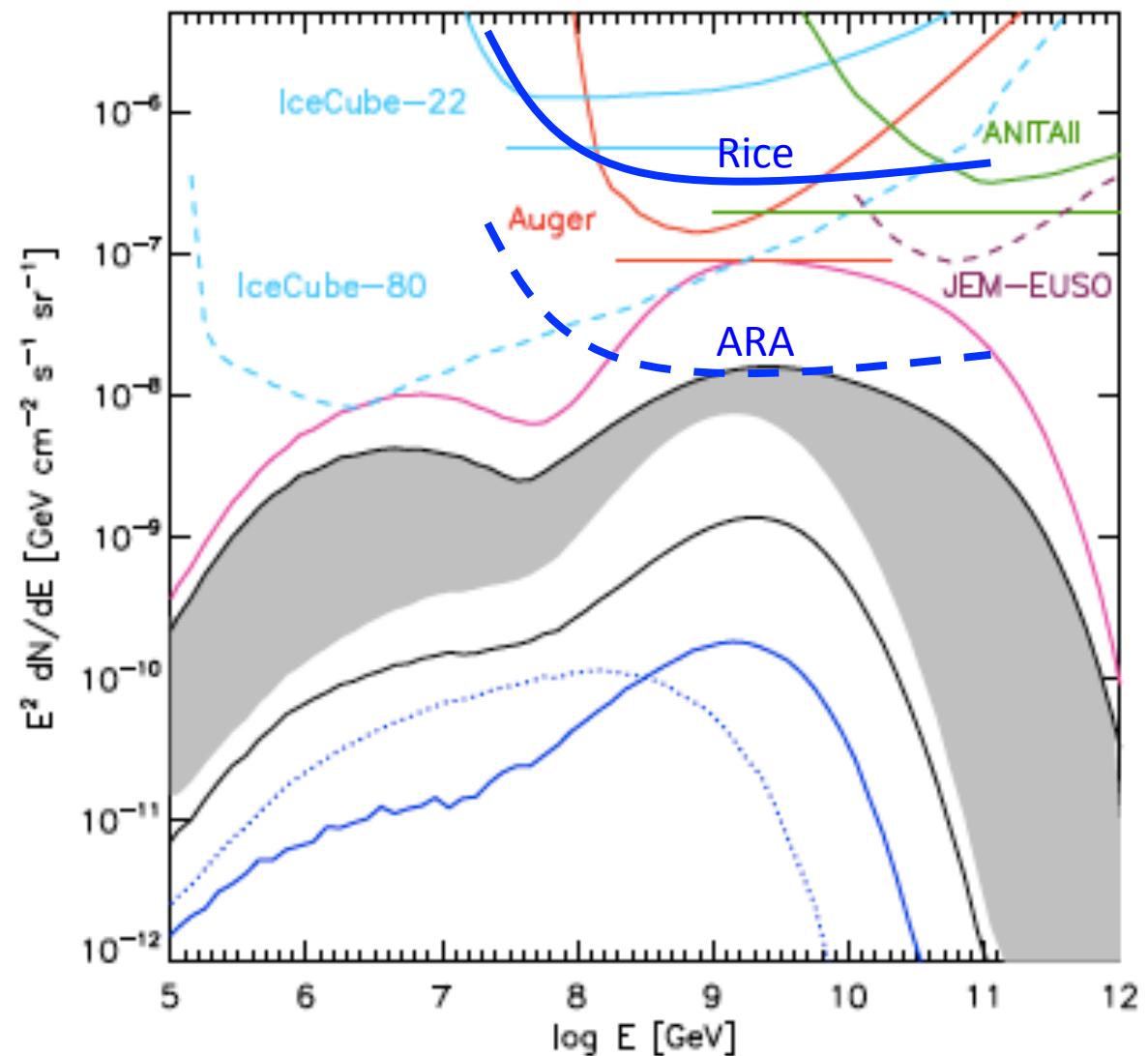
## Fluorescence from Space @ ISS

JAXA & ESA approval depend  
on NASA support (SALMON)  
launched by JAXA vehicle 2016



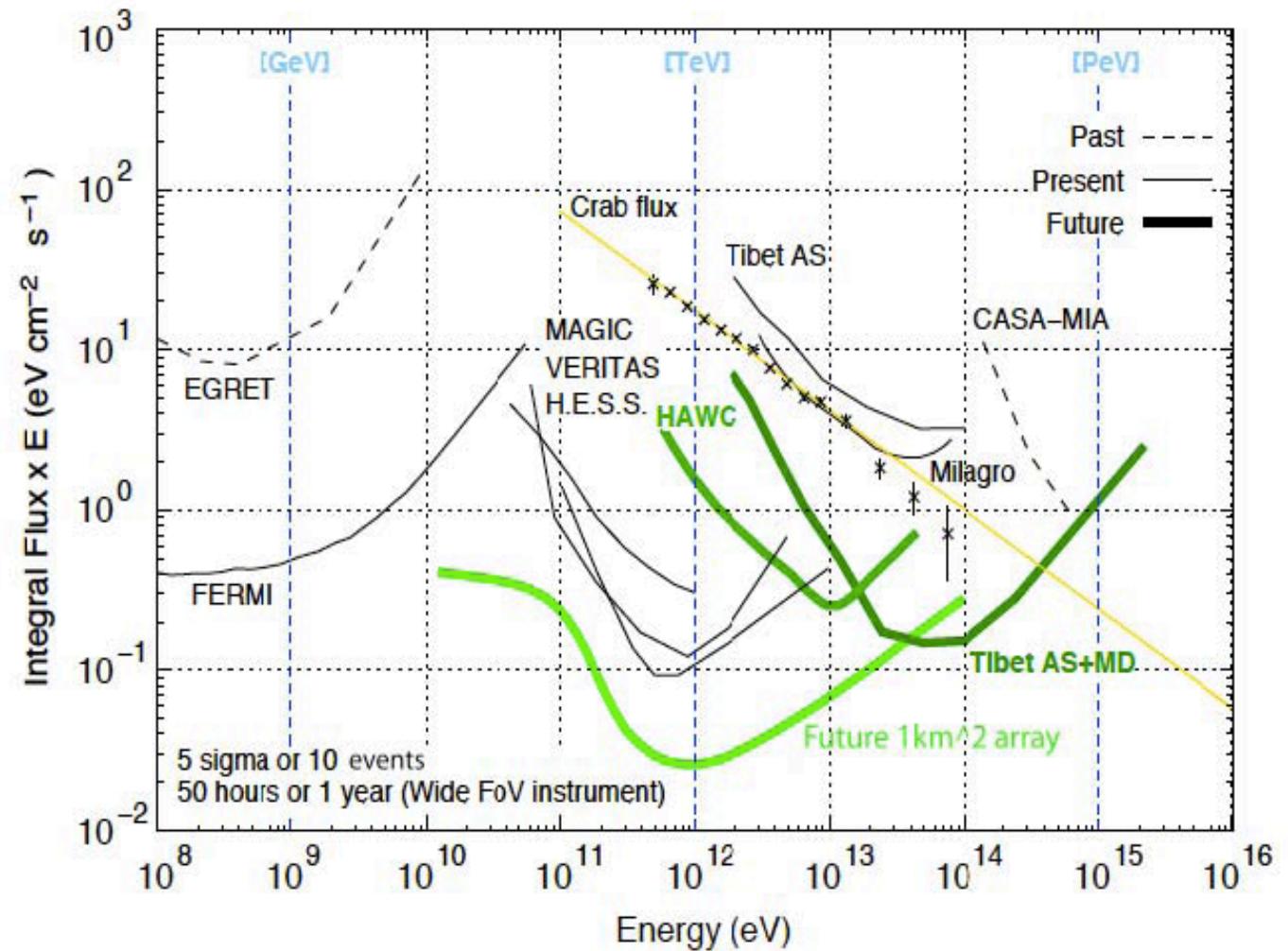
# Tools for HE Neutrinos: Present/Future

Ice and Water  
IceCube,  
Antares,  
**ARA, KM3NeT**  
Space  
ANITA



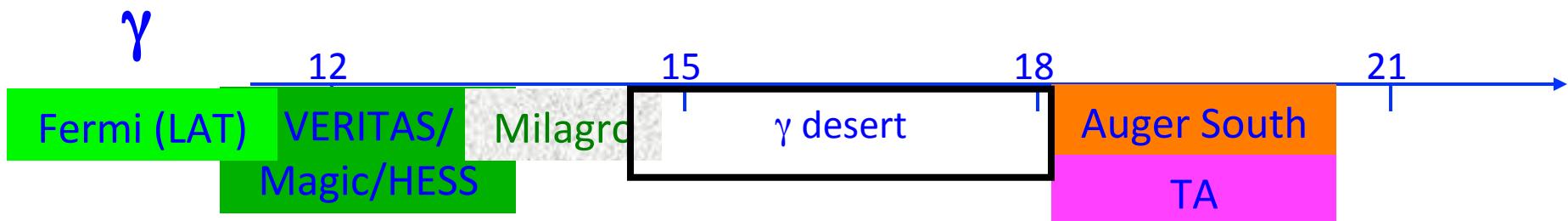
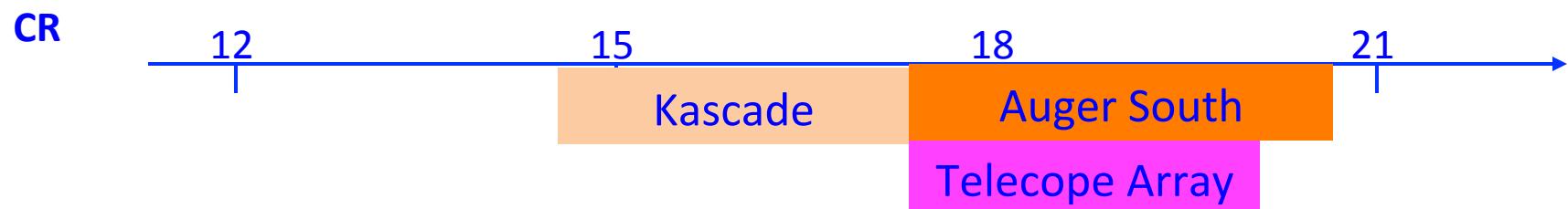
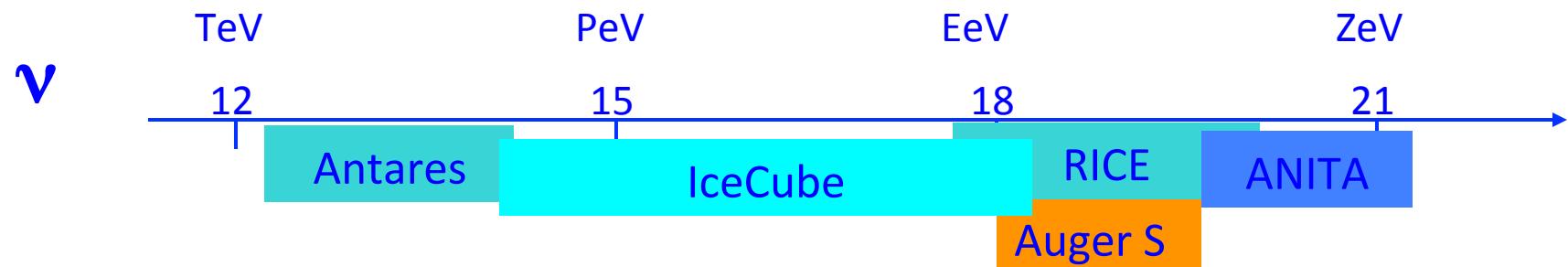
# Tools for HE Gamma-Rays: Present/Future

Ground arrays  
VERITAS, HESS,  
Magic, **Tibet**  
**HAWC, CTA**  
Space  
Fermi



# Particle Astrophysics @ HEs

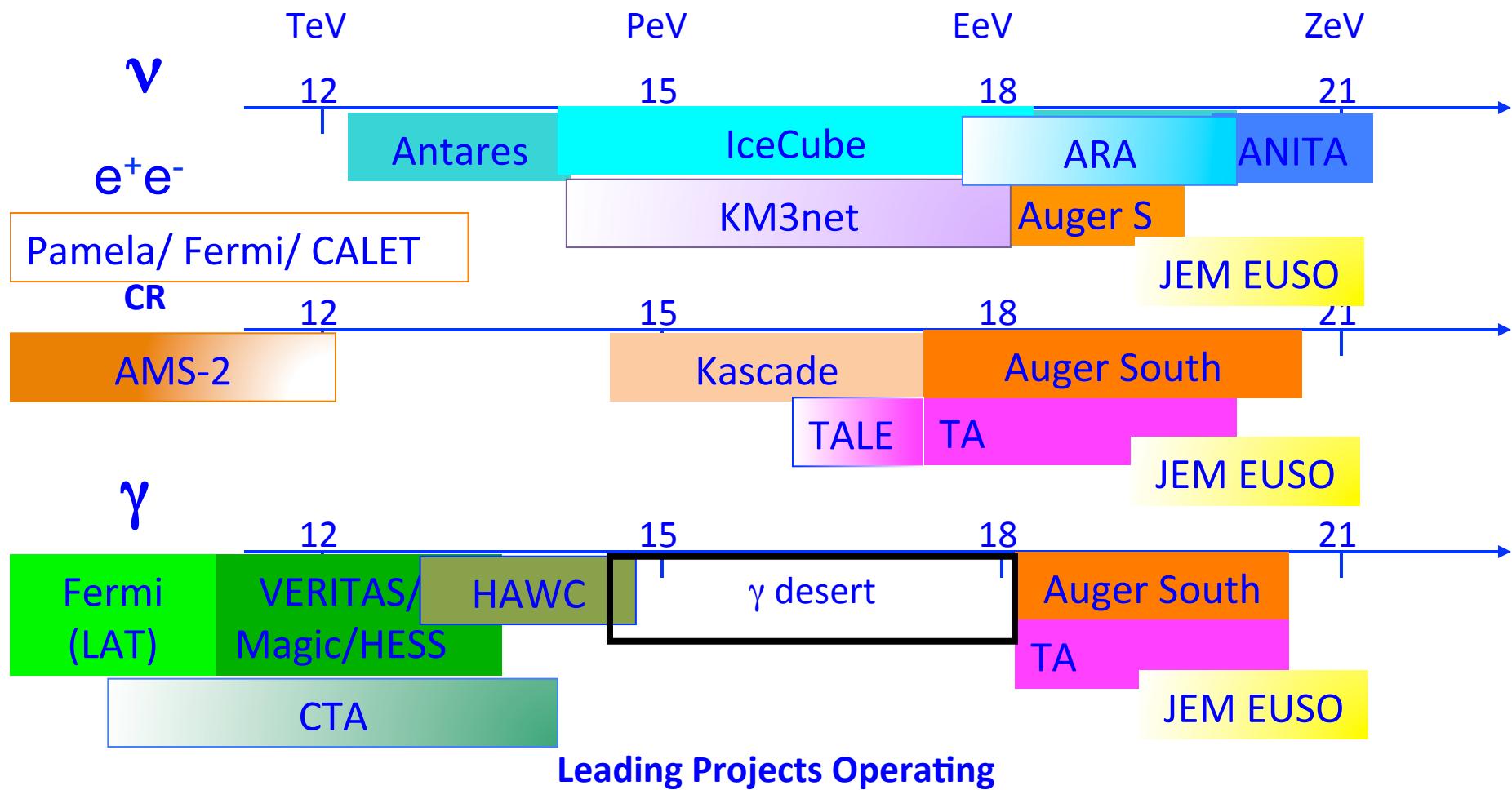
The Energy Frontier



Leading Projects Operating

# Particle Astrophysics @ HEs

## The Energy Frontier



# Questions

Which Questions can Current Tools answer,  
which they cannot?

Which Future tools are crucial for which  
questions?

What R&D is needed to make more sensitive  
experiments/observatories?